NASA TEERM Hexavalent Chrome Alternatives Projects

Engineering Directorate
Kennedy Space Center, FL

August 18, 2011
2011 AF Corrosion Conference

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Report Documentation Page

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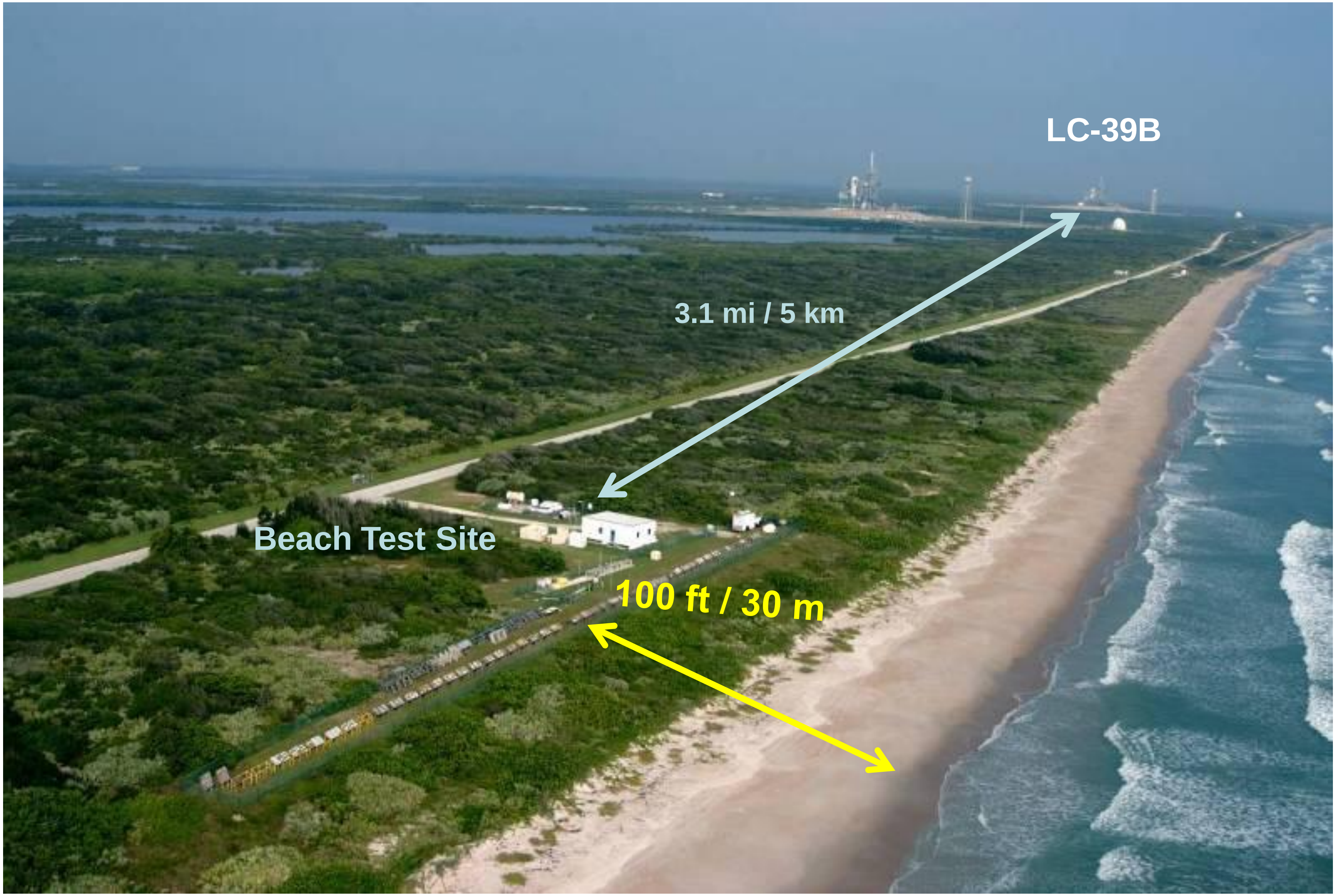
Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

Marine Environment Test Locations



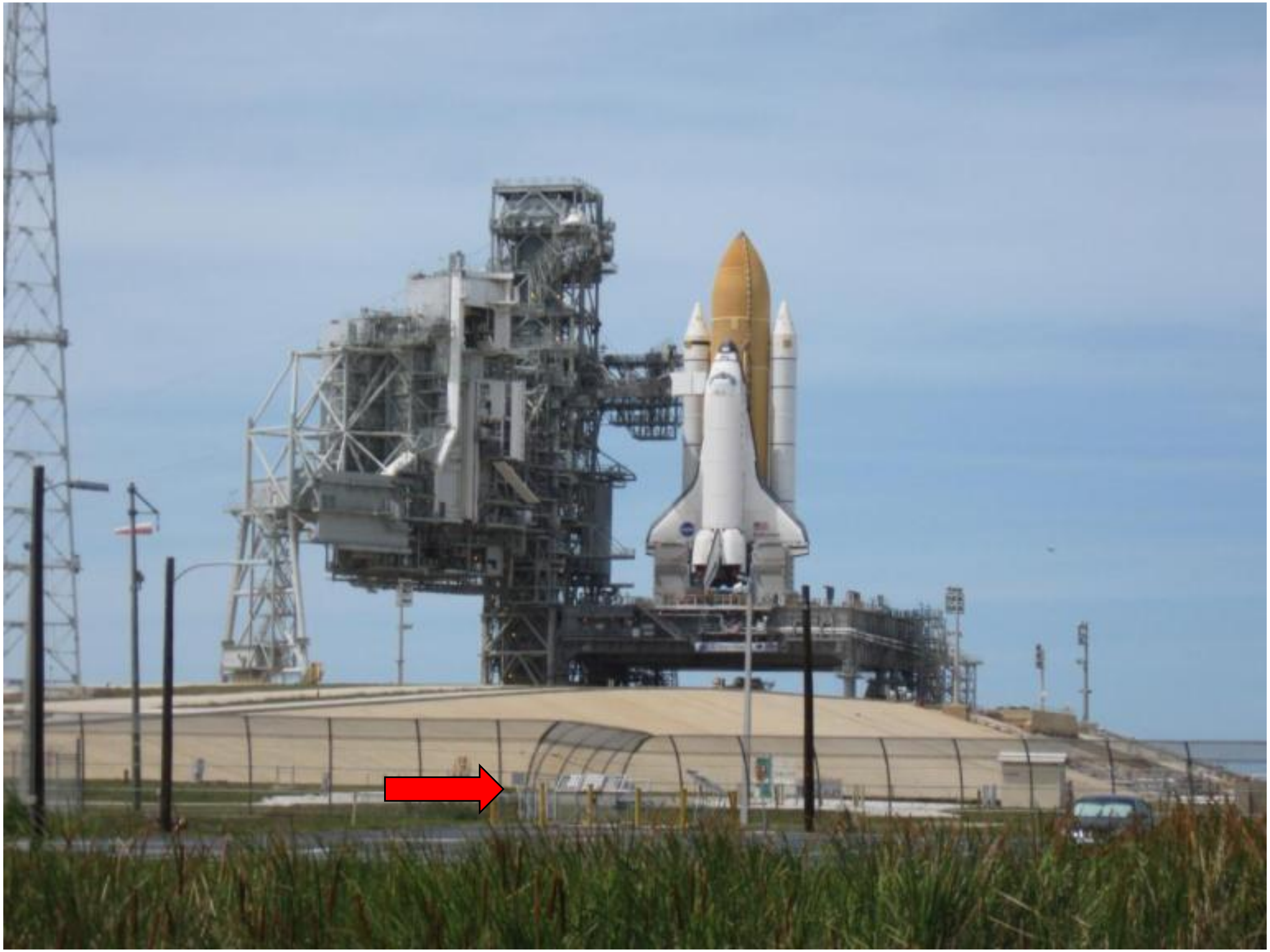
Corrosion Rate Comparison

Location or Region	Type of Environment	µm / year	Corrosion Rate (a) Mils / Year
Esquimalt, Vancouver Island, BC, Canada	Rural Marine	13	0.5
Pittsburgh, PA	Industrial	30	1.2
Cleveland, OH	Industrial	38	1.5
Limon Bay, Panama, CZ	Tropical Marine	61	2.4
East Chicago, IL	Industrial	84	3.3
Brazos River, TX	Industrial Marine	94	3.7
Daytona Beach, FL	Marine	295	11.6
Pont Reyes, CA	Marine	500	19.7
Kure Beach, NC	Marine	533	21
Galeta Point Beach, Panama, CZ	Marine	686	27
Kennedy Space Center, FL	Marine	1070	42

(a) Two-year average…* Data extracted from: S. Coburn, Atmospheric Corrosion, in Metals Handbook, 9th ed, Vol. 1, Properties and Selection, Carbon Steels, American Society for Metals, Metals Park, Ohio, 1978, p. 720.

LC-39B Test Location

LC-39B Test Location



LC-39B Test Location

HISTORIC TESTING AND RESEARCH WITHIN THE AGENCY

External Tank Research

Testing between 1992-2007:

Looking For:

- Replacements for Iridite 14-2 (pretreat)
- Replacements for DeSoto K719 (primer)

Tested:

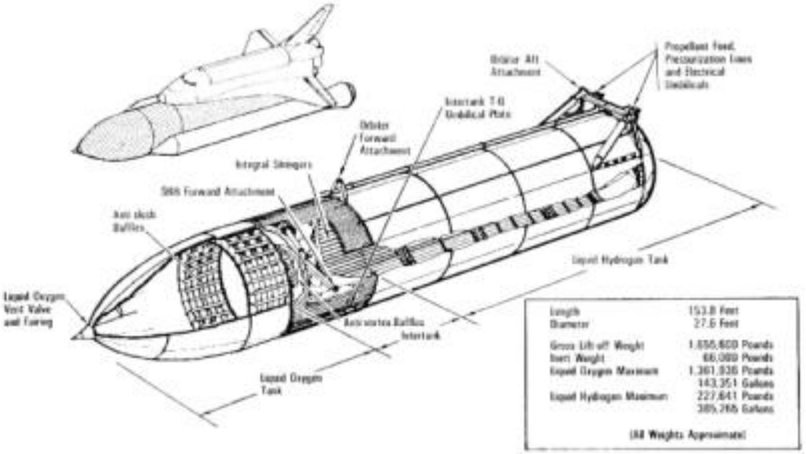
- Tested primers (≈30) → None passed
- Tested pretreatments (≈ 6) → None passed

Positive results:

- TCP (Metalast, Alodine)
- Hentzen Primers (good corrosion protection)

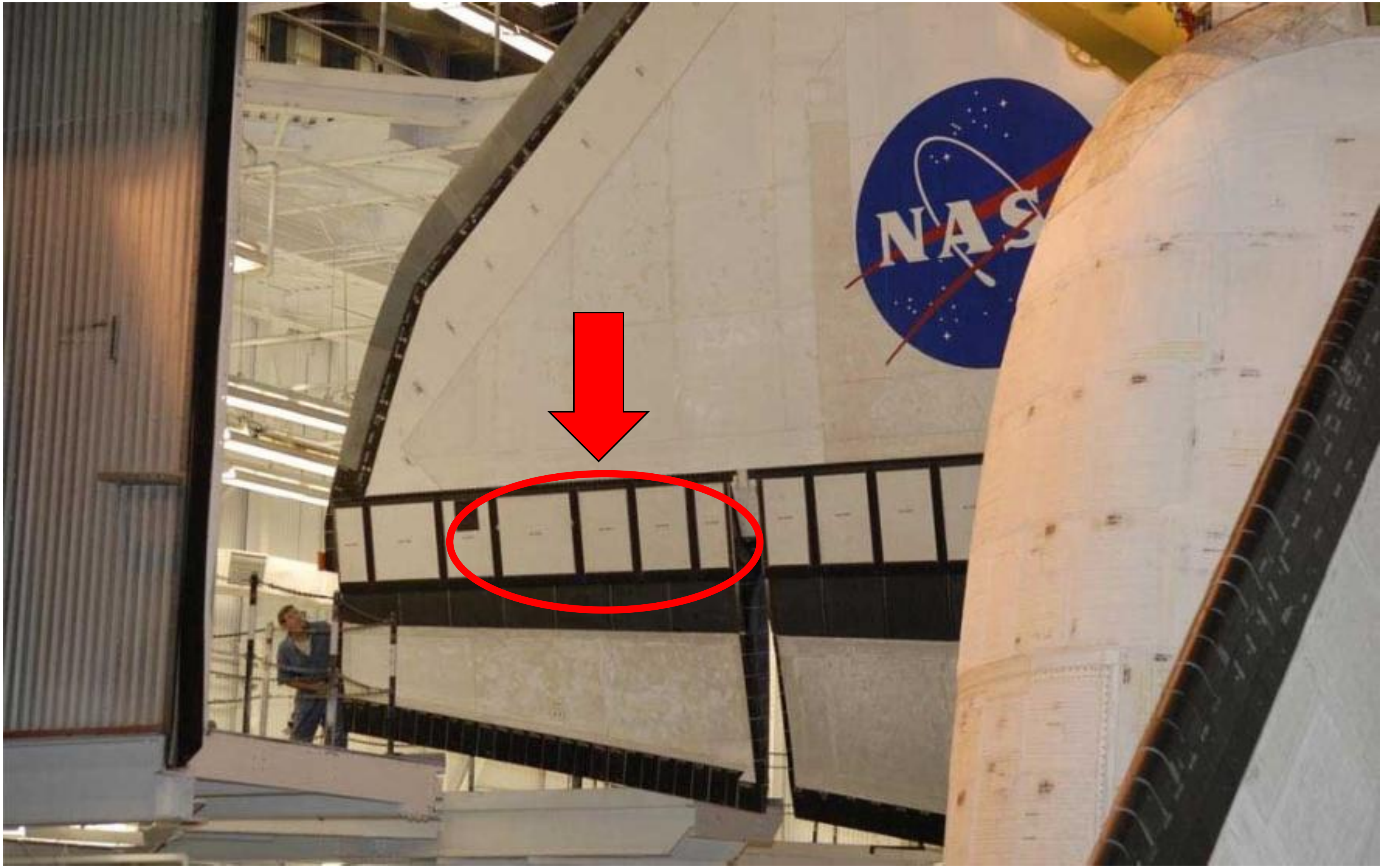
Issues (Very difficult tests to pass):

- Cryoflex Adhesion
- SLA Cryogenic Flexibility
- Corrosion (2000+ Hrs)
- LOX Compatibility



Lightweight External Tank

Orbiter Dem-Val



Orbiter Dem-Val

Columbia (OV-102)
Field Demonstration (1998-2003):

Looking For:

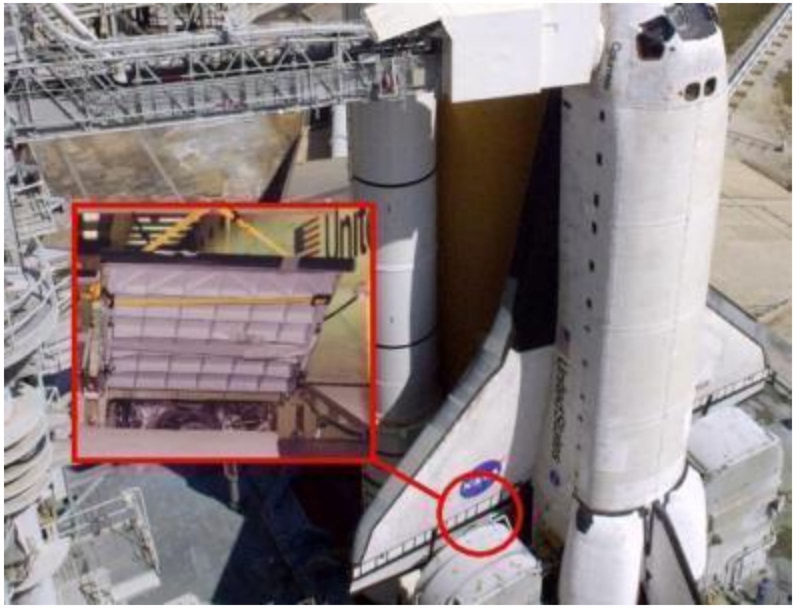
- Replacements for Alodine 1200 (pretreat)
- Replacements for Koropon (primer)

Tested:

- Elevon Cove Seal Doors
- Identified as "drip points" and areas subject to more than average corrosion
- Every-other door coated with Control
- Every-other door coated with Alternative

Coating Tested:

- Dexter Aerospace Materials / Crown Metro Aerospace: 10PW22-2/ECW-119
- Coating performed well in this test for 2+ years at KSC, and performed well in standard tests performed by JGPP.



SRB Implementation

Testing and Qualification of Coating Systems:

Two-Phase Project Resulting in:
- Replacements for Alodine 1200 (pretreat)
- Replacements for Deft 44-GN-7 (primer)
- Replacements for Deft 03-W-127A (topcoat)

Initial Testing:
- 6 Pretreatments, 6 Primers

Secondary Testing:
- 3 Pretreats, 3 Primers → 3 Cr^{+6} Free Passed

Approved Coating Systems for SRB Aluminum

Pretreatment	Primer	Topcoat
Alodine 1201	Deft 44GN7	Deft 03W127
Alodine 1201	Hentzen 05510WEP-X/05511CEH-X	Hentzen 4636WUX-3/4600CHA-SG
Alodine 1201	Lord 9929 A/B	Lord A276
Alodine 5700	Deft 44GN7	Deft 03W127
Alodine 5700	Hentzen 05510WEP-X/05511CEH-X	Hentzen 4636WUX-3/4600CHA-SG
Alodine 5700	Lord 9929 A/B	Lord A276
Chemidize 727	Deft 44GN7	Deft 03W127
Chemidize 727	Lord 9929 A/B	Lord A276

TEERM INITIATED RESEARCH AND TESTING (PAST, PRESENT, FUTURE)

Overview of TEERM Projects

Demonstration / Validation Testing of Coating Systems

Past:

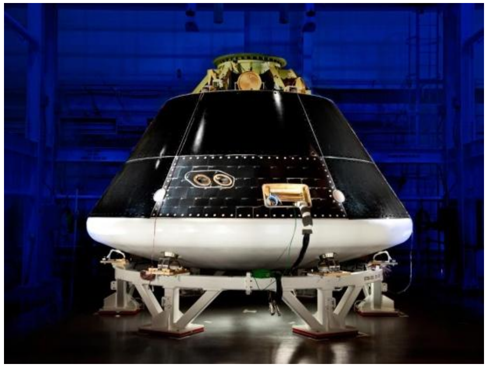
- Phase I – Completed 2007
- Intl. Collaboration NASA/C3P/TAP – C. 2007

Recent Past / Present:

- Phase II
  - JTR Drafted – Will be finalized in CY2011
- Lifecycle Corrosion Project
  - Feb 2011 (Analysis Pending)
  - Corrosion Rate Study – Oct 2010
  - Combined Environment Testing – Nov 2010
  - Mini-CBA of shift away from CrVI – Feb 2011

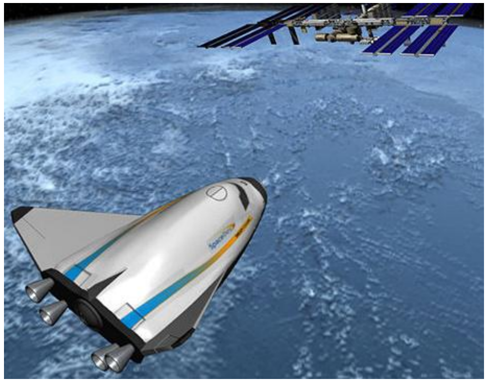
Overview of TEERM Projects

Demonstration / Validation Testing of Coatings



Newly Kicked Off Projects:

- Electronics / Avionics
  - **March 2010** (Development Began)
  - **September 2011** (Panel Preparation Begins)



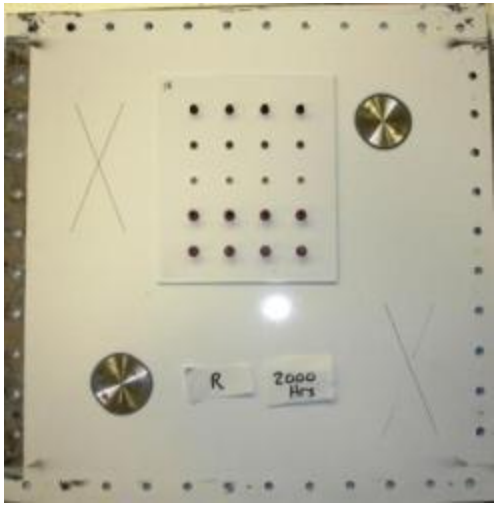
- International Collaboration (ESA/NASA)
  - **March 2010** (Development Began)
  - **June 2011** (Agreement in Place to begin “work”)

- ESTCP Comprehensive Primer Testing
  - **September 2010**

Future:

- Alts. for heavy-lift and commercial space sector
- Cadmium / Chromium for Electronic Connectors
- BR-127 Alternatives (NASA/DOD/ESA) ?

TEERM Phase I



Testing between 2005-2007:

Looking For Systems Alternatives:

- Sys C: Alodine 1200 + Deft 02-Y-40 + Deft 03-GY-321

Substrates:

- 2219, 2195, 6061, 2024 Bare, 2024 Clad, and 7075

Systems Tested:

- Sys T: Alodine 5700 / Sicopoxy 577-630 / Deft 03-GY-321
- Sys N: PreKote / Mg-Rich / Deft 03-GY-321
- Sys H: Alodine 5700 / Hentzen 05510WEP-X / Deft 03-GY-321
- Sys D: Boegel AC-131CB / Dupont Corlar 13570S / Deft 03-GY-321
- Sys S: PreKote / AquaSurTec Crosslinker / AquaSurTec D45

Positive results, (but not fully successful):

- System T, System N, System H

Tests Performed:

- 3000 Hr. Salt-Spray, 2,000 Hr. Cyclic Corrosion, Filiform Corrosion, Dissimilar Metals Corrosion, SAS, Hydrogen Embrittlement & Adhesion

Hex-Chrome Free Systems Phase I
3000 Hour Salt Fog Results

	Primer and Topcoat	Primer Only	Primer and Topcoat	Primer Only	Primer and Topcoat	Primer Only	Primer and Topcoat	Primer Only	Primer and Topcoat	Primer Only	Primer and Topcoat	Primer Only
Coating System	2219-T81	2219-T81	2024-T3	2024-T3	2024-T3 Clad	2024-T3 Clad	7075-T6	7075-T6	6061-T6	6061-T6	2195-T8M4	2195-T8M4
C	C2-1	C3-1	C4-1	C5-1	C6-1	C7-1	C8-1	C9-1	C10-1	C11-1	C12-1	C13-1
	C2-2	C3-2	C4-2	C5-2	C6-2	C7-2	C8-2	C9-2	C10-2	C11-2	C12-2	C13-2
T	T2-1	T3-1	T4-1	T5-1	T6-1	T7-1	T8-1	T9-1	T10-1	T11-1	T12-1	T13-1
	T2-2	T3-2	T4-2	T5-2	T6-2	T7-2	T8-2	T9-2	T10-2	T11-2	T12-2	T13-2
N	N2-1	N3-1	N4-1	N5-1	N6-1	N7-1	N8-1	N9-1	N10-1	N11-1	N12-1	N13-1
	N2-2	N3-2	N4-2	N5-2	N6-2	N7-2	N8-2	N9-2	N10-2	N11-2	N12-2	N13-2
H	H2-1	H3-1	H4-1	H5-1	H6-1	H7-1	H8-1	H9-1	H10-1	H11-1	H12-1	H13-1
	H2-2	H3-2	H4-2	H5-2	H6-2	H7-2	H8-2	H9-2	H10-2	H11-2	H12-2	H13-2
D	D2-1	D3-1	D4-1	D5-1	D6-1	D7-1	D8-1	D9-1	D10-1	D11-1	D12-1	D13-1
	D2-2	D3-2	D4-2	D5-2	D6-2	D7-2	D8-2	D9-2	D10-2	D11-2	D12-2	D13-2
S	S2-1	S3-1	S4-1	S5-1	S6-1	S7-1	S8-1	S9-1	S10-1	S11-1	S12-1	S13-1
	S2-2	S3-2	S4-2	S5-2	S6-2	S7-2	S8-2	S9-2	S10-2	S11-2	S12-2	S13-2

3000 Hrs

< 2500 Hrs

< 2000 Hrs

< 1500 Hrs

< 500 Hrs

TEERM International Collaboration

Dem / Val & Field-testing of Coating Systems

Looking For:

- Replacements for hex-chrome pretreatments
- Replacements for hex-chrome primers

Coatings Tested:

- Sys M: M790E + Aviox CF + Aviox Finish 77702
- Sys P: PreKote SP + Aviox CF + Aviox Finish 77702

Laboratory Testing:

- Gloss, Color, Adhesion, Impact, Flexibility, Fluid Resistance, Filiform Corrosion, Salt-Spray Corrosion, Artificial Weathering, Stripability, Restoration & Heat Stability

Field Testing:

- Painted exterior service door of a TAP Airbus A319 (2004)
- Visual inspections (2+ Yrs) appeared favorable with no visual signs of corrosion, deterioration in thickness or in color. (2007)

TEERM Phase II (Non-Chrome Systems Testing)

Laboratory & Atmospheric Testing of Coating Systems

Coatings Tested:

- Systems H, N, T, P + Others
- CxP contributed other coatings to be tested

Pretreatments:

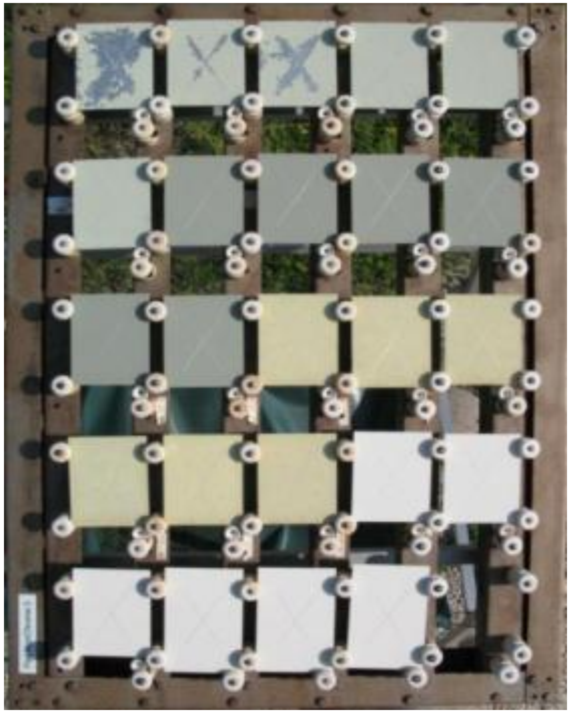
- Alodine 1200, Iridite 14-2, Alodine 5200, Surtec 650, Prekote, Metalast TCP-HF, Metalast TCP-HF/EPA, Alodine 5900T, VpCI-440

Primers:

- Koropon (515X346 / 910x520) (Control), STMK719 Superkoropon (Control), ANAC / Mg Rich XP417-183, Hentzen 05510WEP-X / 05511CEH-X, Hentzen 16708TEP / 16709CEH (Type I), Hentzen 7176KEP / 16709CEH (Type II), Sicopoxy 577-630, Aviox CF Primer (TC) 330312, Deft 44GN098 (Waterborne), Deft 02GN084 (High Solid), VpCI-373 (Vapor Phase CI), Lockheed Martin (CF Epoxy Primer), Ecoprime CF, Hentzen Epoxzen

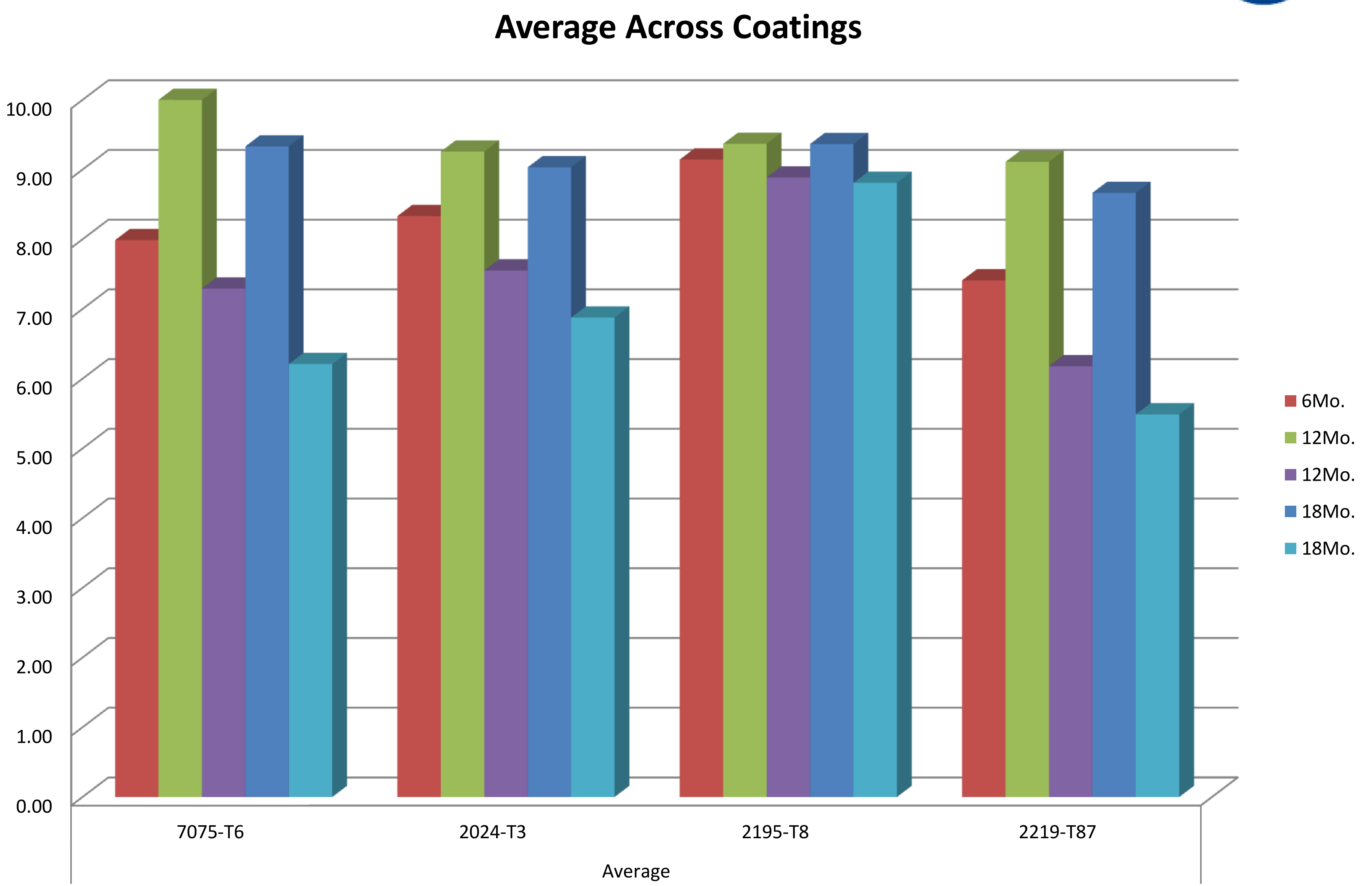
Testing:

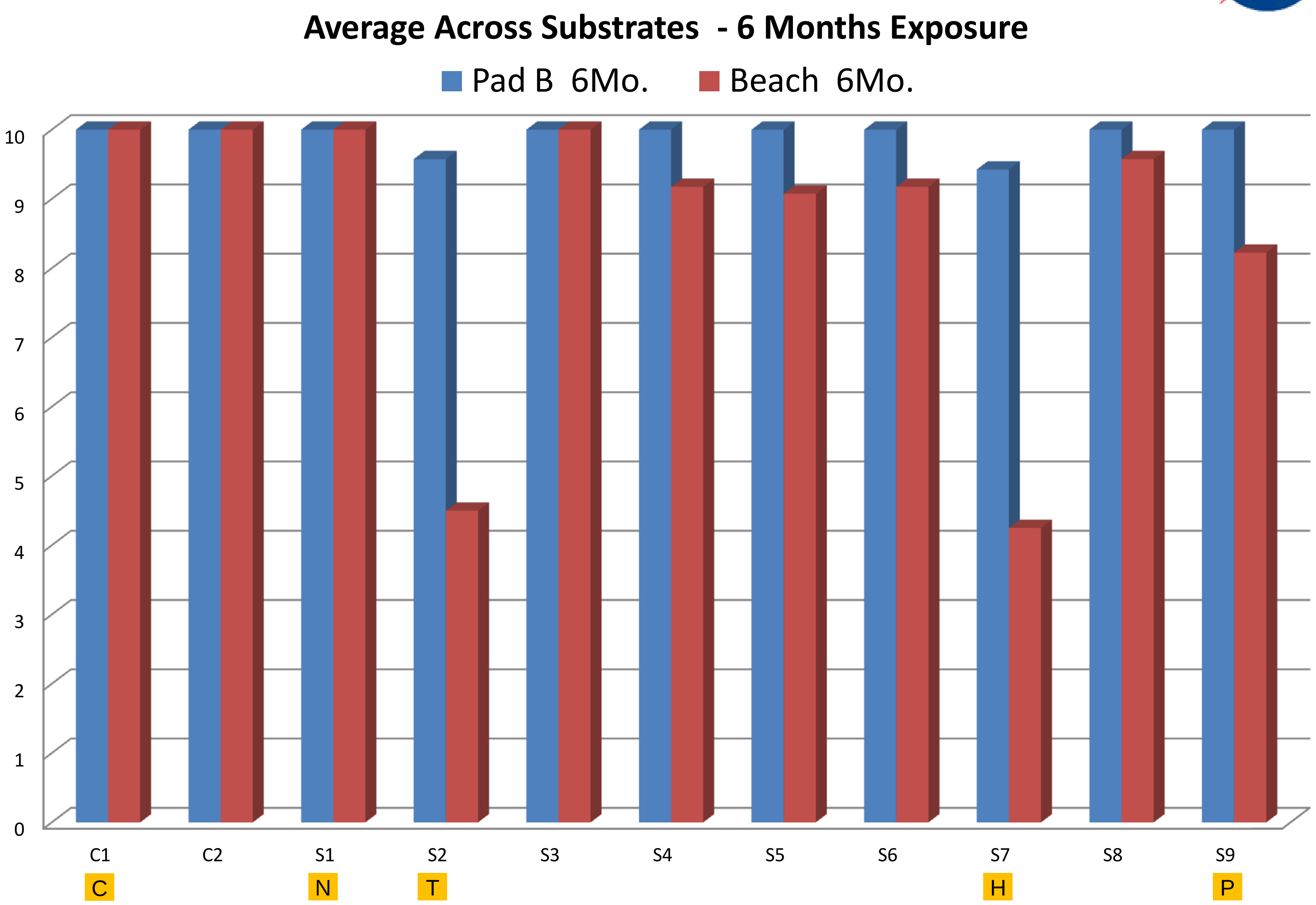
- Atmospheric Exposure (Beach & Pad), Adhesion, Bare Corrosion Resistance (limited), Corrosion Rate
  (Field Testing Complete in November 2010)

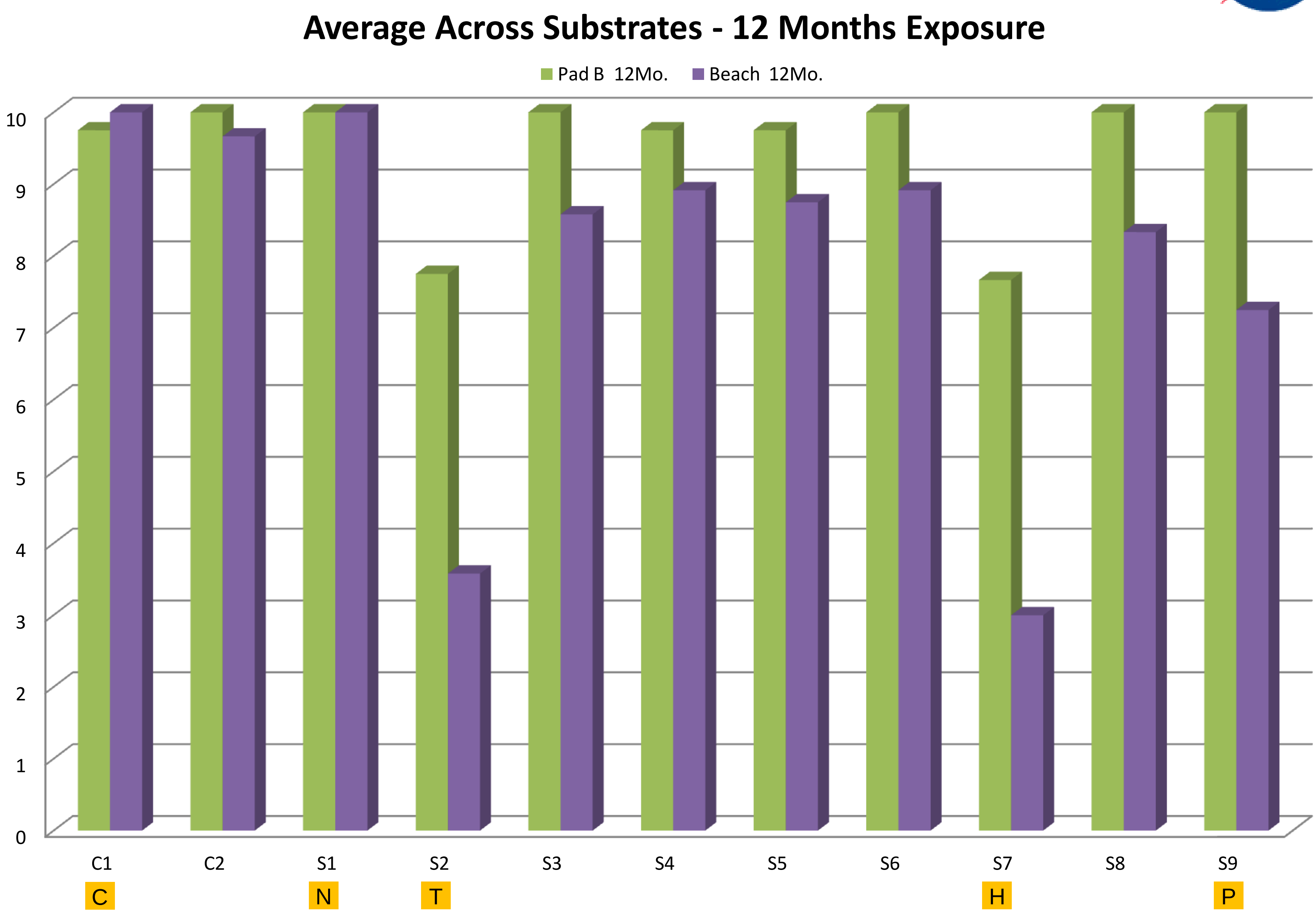


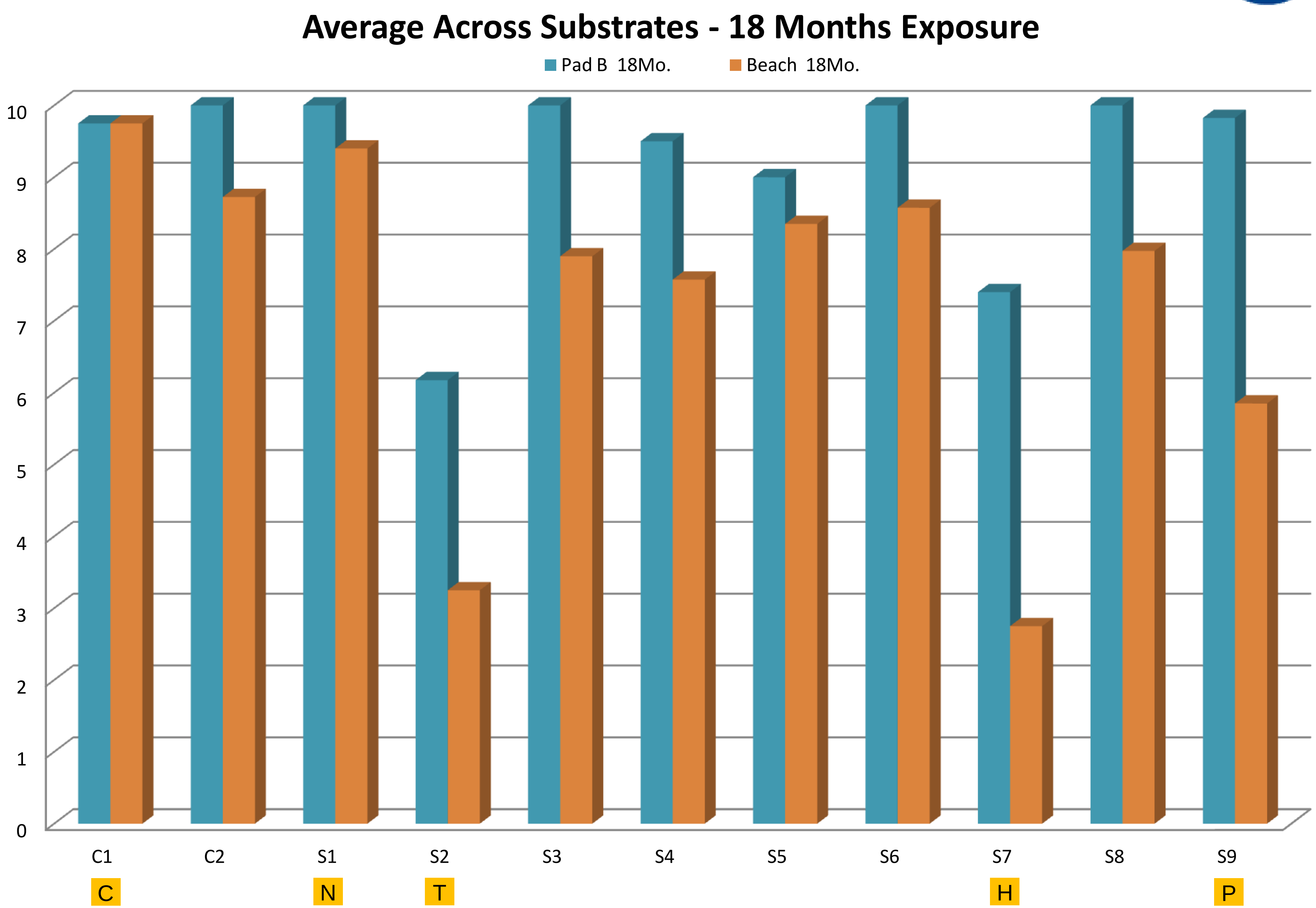
Phase II Coating Systems

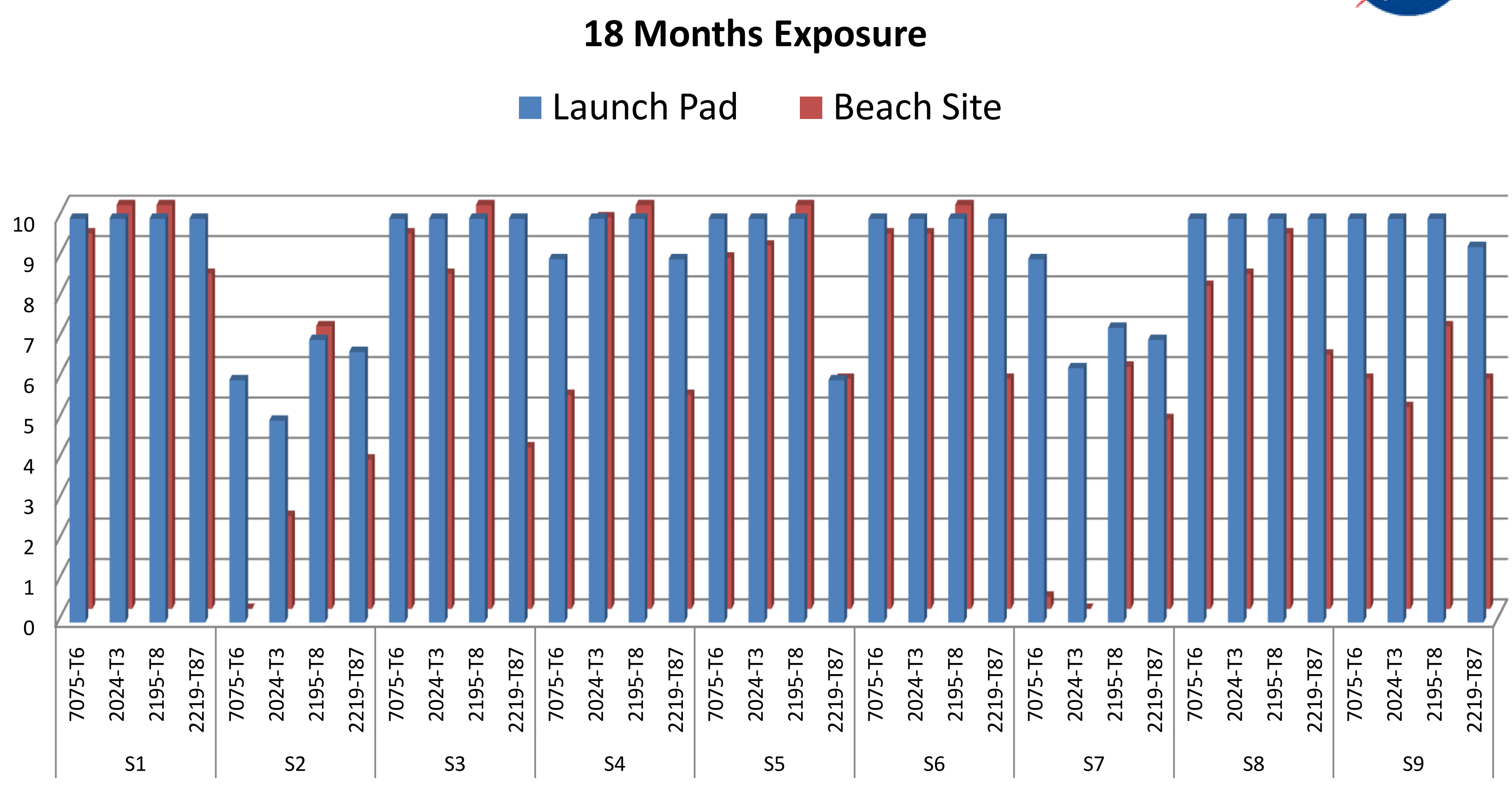
Ph I Code	Ph II Code	Pretreatment	Primer	Topcoat
C	C1	Alodine 1200s	Koropon (515X346 / 910x520)	PRC-Desoto CA8211/F27925
N/A	C2	None	Koropon (515X346 / 910x520)	PRC-Desoto CA8211/F27925
N	S1	PreKote	ANAC / Mg Rich	PRC-Desoto CA8211/F27925
T	S2	Alodine 5200	Sicopoxy 577-630	PRC-Desoto CA8211/F27925
N/A	S3	METALAST TCP-HF/EPA	Deft 084 (High Solid)	PRC-Desoto CA8211/F27925
N/A	S4	METALAST TCP-HF/EPA	Deft 098 (Waterborne)	PRC-Desoto CA8211/F27925
N/A	S5	METALAST TCP-HF/EPA	Hentzen (Type I - 16708TEP / 16709 CEH)	PRC-Desoto CA8211/F27925
N/A	S6	METALAST TCP-HF/EPA	Hentzen (Type II - 7176KEP / 16709 CEH)	PRC-Desoto CA8211/F27925
H	S7	Alodine 5200	Hentzen Primer (05510WEP-X / 05511CEH-X)	PRC-Desoto CA8211/F27925
N/A	S8	VpCI-440	VpCI-373	PRC-Desoto CA8211/F27925
P	S9	PreKote	Aviox CF Primer (TC)	PRC-Desoto CA8211/F27925


Average Across Coatings
10.00
9.00
8.00
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00
7075-T6
2024-T3
2195-T8
2219-T87
Average
6Mo.
12Mo.
12Mo.
18Mo.
18Mo.


Average Across Substrates - 6 Months Exposure
Pad B 6Mo.
Beach 6Mo.
10
9
8
7
6
5
4
3
2
1
0
C1
C2
S1
S2
S3
S4
S5
S6
S7
S8
S9
C
N
T
H
P


Average Across Substrates - 12 Months Exposure
Pad B 12Mo.
Beach 12Mo.
10
9
8
7
6
5
4
3
2
1
0
C1
C2
S1
S2
S3
S4
S5
S6
S7
S8
S9
C
N
T
H
P


Average Across Substrates - 18 Months Exposure
Pad B 18Mo.
Beach 18Mo.
0
1
2
3
4
5
6
7
8
9
10
C1
C2
S1
S2
S3
S4
S5
S6
S7
S8
S9
C
N
T
H
P


18 Months Exposure
Launch Pad
Beach Site
0
1
2
3
4
5
6
7
8
9
10
7075-T6
2024-T3
2195-T8
2219-T87
S1
S2
S3
S4
S5
S6
S7
S8
S9

N T H P

Phase II Nomenclature	Phase I Nomenclature	Phase I Testing: B117 2219-T81	Phase I Testing: B117 2195-T8M4	Phase II Testing: Beach Duration	Phase II Testing: Beach 2219-T81	Phase II Testing: Beach 2195-T8M4
S2	T	T2-1	T12-1	6 Mos	5	7
				12 Mos	4.66	6.66
		T2-2	T12-2	18 Mos	3.70	7.00
				Avg.	4.45	6.89
S1	N	N2-1	N12-1	6 Mos	10	10
				12 Mos	10	10
		N2-2	N12-2	18 Mos	8.30	10
				Avg.	9.43	10
S7	H	H2-1	H12-1	6 Mos	5	6
				12 Mos	4.66	6
		H2-2	H12-2	18 Mos	4.70	6
				Avg.	4.786667	6

Phase I B117 Exposure	
Hrs Exposed w/o Failure	
(pink)	< 500 Hrs
(yellow)	< 1500 Hrs
(light blue)	< 2000 Hrs
(light green)	< 2500 Hrs
(green)	3000 Hrs

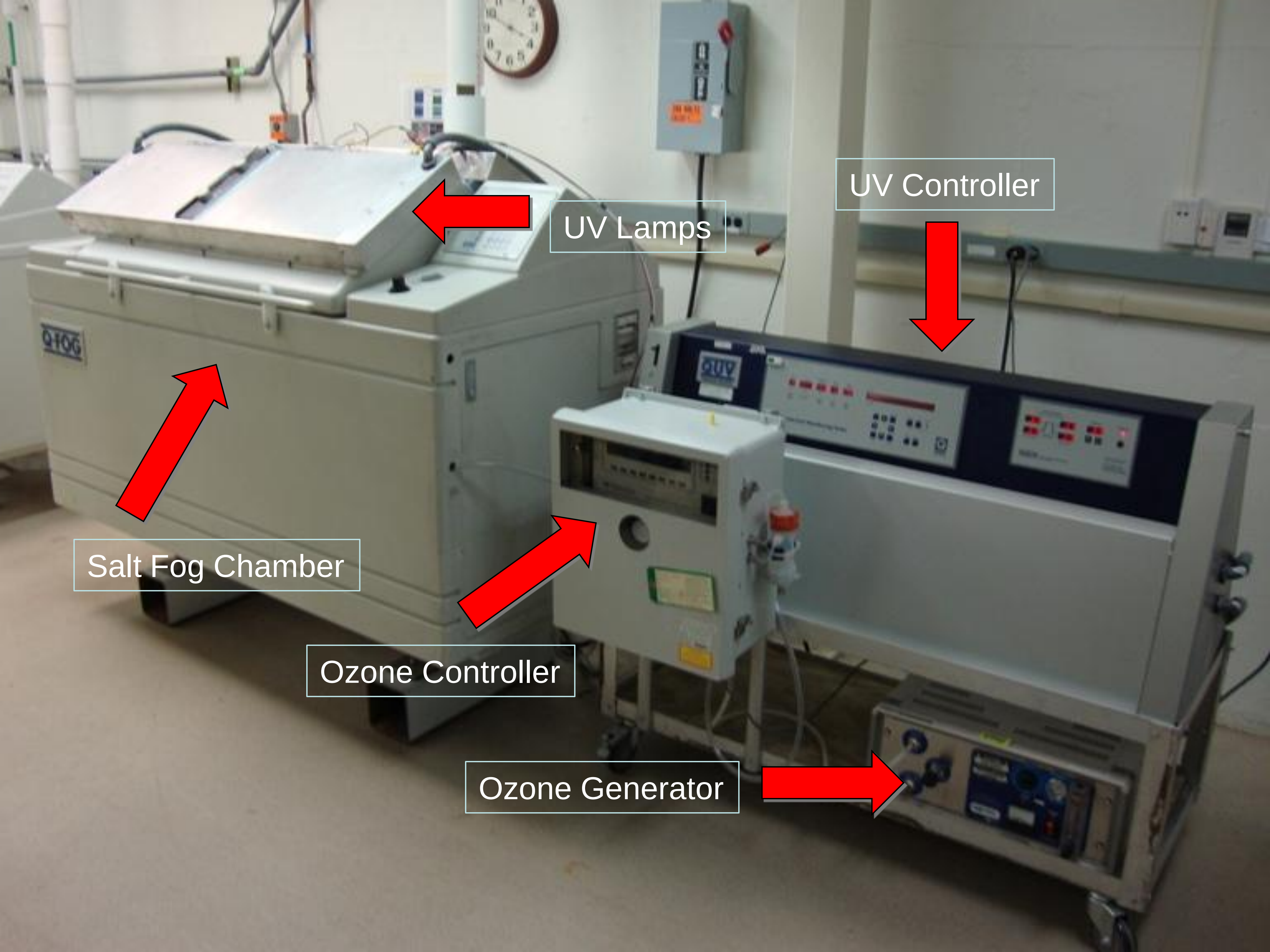
Phase II Beach Exposure	
Panel Rating	
(pink)	<5
(yellow)	<7
(light blue)	<8
(light green)	<10
(green)	=10

2219 – Coatings Passed in Lab

2219 - Coatings Failed in the Field

Combined Environment

New Test Method
(Early Development)


UV Controller
UV Lamps
Salt Fog Chamber
Ozone Controller
Ozone Generator
Q-FOG
QUV

New Project – March 2010

Hexavalent Chrome Free Coatings for Electronics / Avionics

Project Participants

- NASA
  - Multiple Centers
- Navy
  - Multiple Commands
- Air Force
  - Multiple Organizations
- Army
  - Multiple Divisions
- MDA
- DMEA
- AFSPC
- Sandia

- Harris
- USA
- Northrop Grumman
- Honeywell
- Spirit AeroSystems
- Lockheed Martin
- SpaceX
- Hamilton Sundstrand
- Raytheon
- Selex Galileo
- Atlantic Inertial Systems
- University of Maryland
- AAI Corporation
- United Technologies Research Center
- Missouri University of Science and Technology

- AIA
- ATK
- Celestica
- ComDev
- Medtronic
- General Dynamics
- GE
- Boeing
- BAE Systems
- Garmin
- Rockwell Collins
- Tyco Electronics

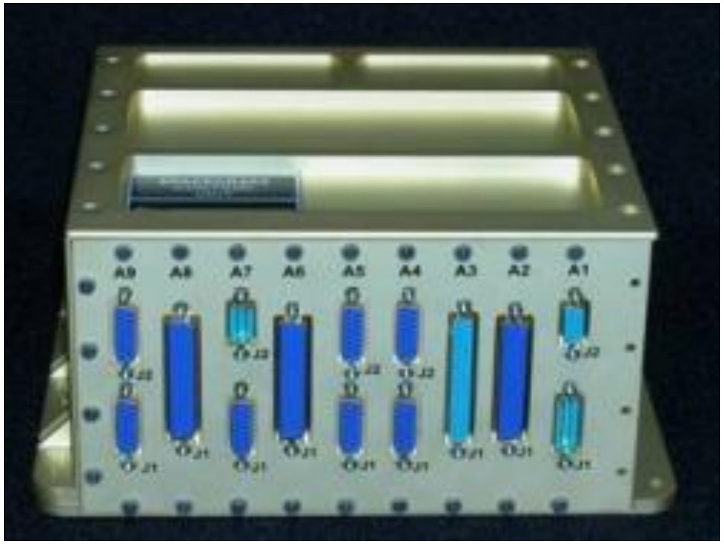
Hex Chrome Free Coatings for Electronics (NASA-DoD)

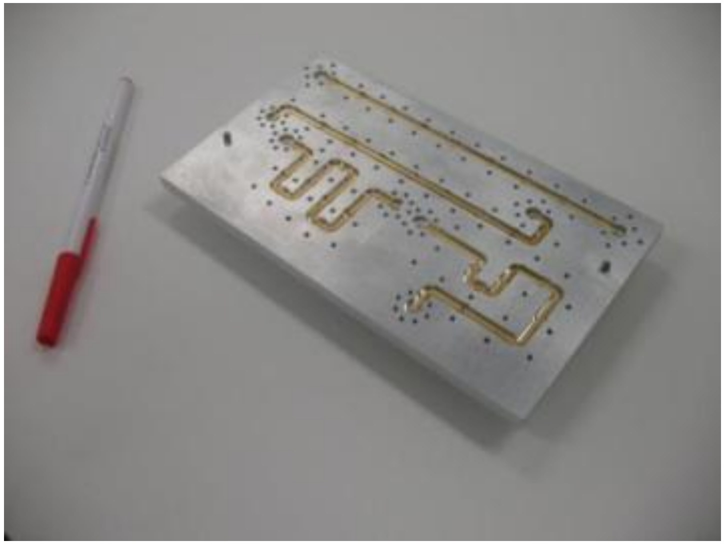
Description:

- Identification, demonstration and validation of hexavalent-chrome free coatings for aerospace applications.
- Evaluate and test individual coatings and systems (pretreatment, primer and topcoat) as replacements for hexavalent chrome coatings in aircraft and aerospace avionics applications.

Drivers:

- Hex-Chrome PEL
  - 5 micrograms of Cr(VI) per cubic meter of air
- RoHS
  - Restriction of Hazardous Substances Directive
- DFAR
  - Minimizing Use of Hexavalent Chromium (DFARS Case 2009-D004)
  - The draft final rule is currently being reviewed
    - Office of Information and Regulatory Affairs
      - Office of Management and Budget





Hex Chrome Free Coatings for Electronics (NASA-DoD)

Tier I Testing:

- Salt Spray Resistance
  - ASTM B 117
  - Surface Resistance (ASTM D 257)
  - Contact Electrical Resistance (81706)
- Cyclic Corrosion
  - ASTM G 85, Annex 5
  - Surface Resistance (ASTM D 257)
  - Contact Electrical Resistance (81706)
- 18-Month Marine Environment
  - KSC Beach Corrosion Test Site
  - Surface Resistance (ASTM D 257)
  - Contact Electrical Resistance (81706)
- Patti-Jr. Pull-Off Adhesion Test
  - ASTM D 4541
- Cross-Cut Tape Test
  - ASTM D 3359, Procedure B
- Wet Tape Paint Adhesion
  - FED-STD-141, Method 6301.3

Hex Chrome Free Coatings for Electronics (NASA-DoD)

Tier II Testing:

- EMI (electromagnetic interference) + baseline
- RFI (radio frequency interference) + baseline

Shielding of electronic enclosures is critical for EMI. The main leakage is through seams and apertures. Seams have either direct metal-to-metal contact or a gasket with fasteners to apply recommended pressure. Continuous electrical contact along the seam is required to maintain the shielding. Therefore the direct contact resistance or indirect contact resistance through the gasket is important. The surface treatment of the metal in the seams directly affects the contact resistance.

- Repair / Rework:

Hex-chrome free pretreatments will require extensive analysis before being qualified for repair / rework procedures. Application processes, procedures and equipment will need to be evaluated as well.

Areas of Need

Other Hex Chrome Free Project Need Areas

- Hex-chrome Bond Primer Alternatives
  - BR 127 (Cytec Industries)
- Hex-chrome free coatings used on space hardware
  - Satellites (largely unaddressed)
  - Liquid fueled launchers (very difficult performance requirements)
  - Outer mold line applications (implementation woes)
- Hex-chrome and Cadmium plating alternatives for fasteners
- Hex-chrome and Cadmium plating alternatives for electrical connectors
  - Many attempting to address with few solutions (compatibility issues)
- Hex-chrome free high temperature sealants (Polysulfide Sealants)
- Hex-chrome free corrosion prevention compounds (CPCs) / lubricants

Questions?

NASA TEERM Principal Center

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Backup Slides

Questions?

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6 & 12 Months Exposure

	Coating System	Substrate	6-Months		12-Months	
			Pad B	Beach	Pad B	Beach
C	C1	2024-T3	10	10	10	10
	C2	2024-T3	10	10	10	10
N	S1	2024-T3	10	10	10	10
T	S2	2024-T3	10	4	7	2.66
	S3	2024-T3	10	10	10	8.66
	S4	2024-T3	10	10	10	10
	S5	2024-T3	10	10	10	9.33
	S6	2024-T3	10	10	10	10
H	S7	2024-T3	10	2.7	6.33	0
	S8	2024-T3	10	10	10	9
P	S9	2024-T3	10	8.3	10	8.33

Coating System	Substrate	6-Months		12-Months		
		Pad B	Beach	Pad B	Beach	
C1	7075-T6	10	10	9	10	C
C2	7075-T6	10	10	10	8.66	
S1	7075-T6	10	10	10	10	N
S2	7075-T6	10	2	10	0.33	T
S3	7075-T6	10	10	10	10	
S4	7075-T6	10	10	10	10	
S5	7075-T6	10	10	10	10	
S6	7075-T6	10	10	10	9.66	
S7	7075-T6	10	3.3	10	1.33	H
S8	7075-T6	10	9.3	10	8	
S9	7075-T6	10	7.3	10	6.33	P

	Coating System	Substrate	6-Months		12-Months	
			Pad B	Beach	Pad B	Beach
C	C1	2195-T8	10	10	10	10
	C2	2195-T8	10	10	10	10
N	S1	2195-T8	10	10	10	10
T	S2	2195-T8	8.3	7	7	6.66
	S3	2195-T8	10	10	10	10
	S4	2195-T8	10	10	10	10
	S5	2195-T8	10	10	10	10
	S6	2195-T8	10	10	10	10
H	S7	2195-T8	10	6	7.33	6
	S8	2195-T8	10	10	10	10
P	S9	2195-T8	10	9.3	10	7.33

Coating System	Substrate	6-Months		12-Months		
		Pad B	Beach	Pad B	Beach	
C1	2219-T87	10	10	10	10	C
C2	2219-T87	10	10	10	10	
S1	2219-T87	10	10	10	10	N
S2	2219-T87	10	5	7	4.66	T
S3	2219-T87	10	10	10	5.66	
S4	2219-T87	10	6.7	9	5.66	
S5	2219-T87	10	6.3	9	5.66	
S6	2219-T87	10	6.7	10	6	
S7	2219-T87	7.7	5	7	4.66	H
S8	2219-T87	10	9	10	6.33	
S9	2219-T87	10	8	10	7	P

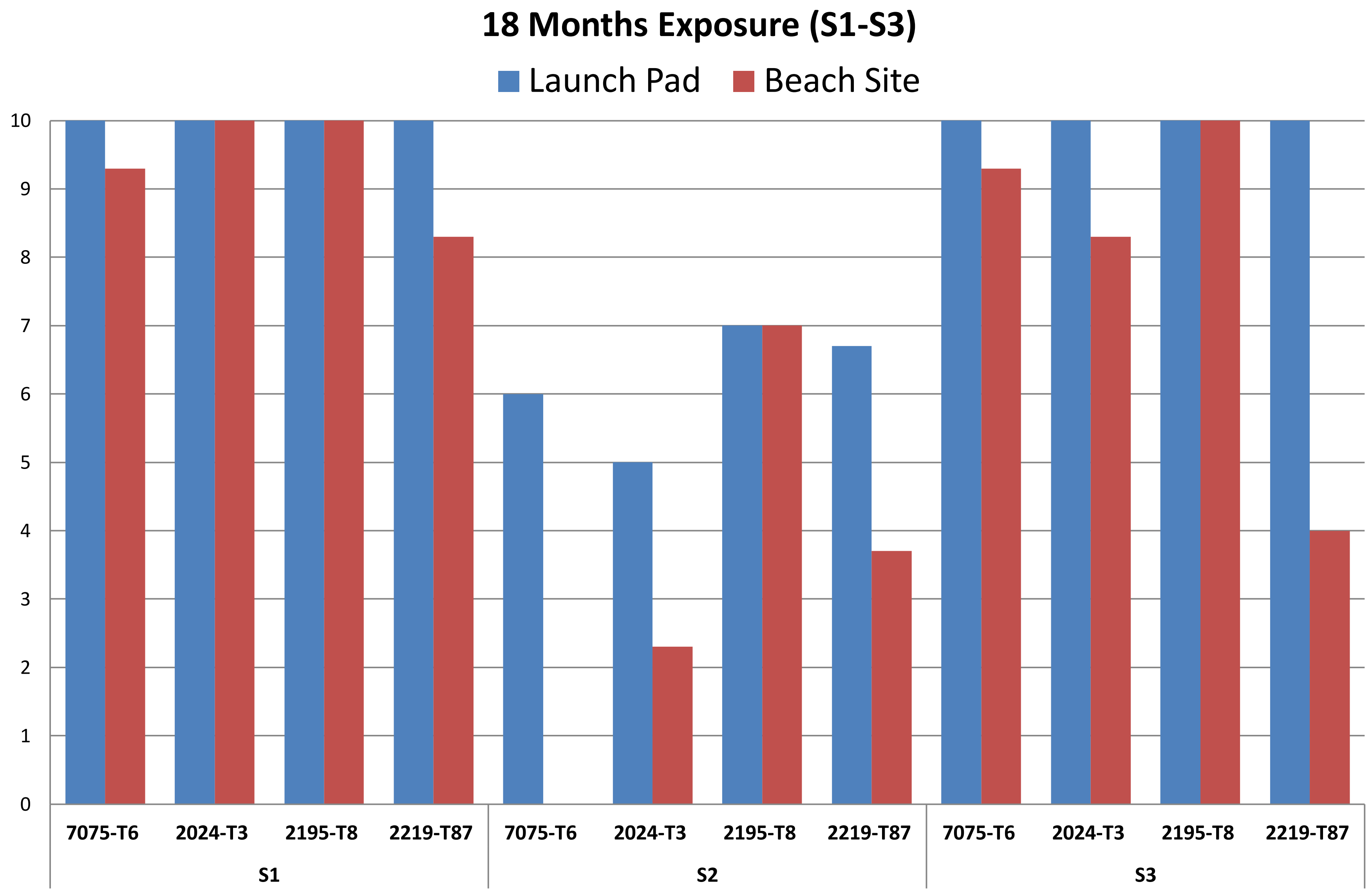
18 Months Exposure

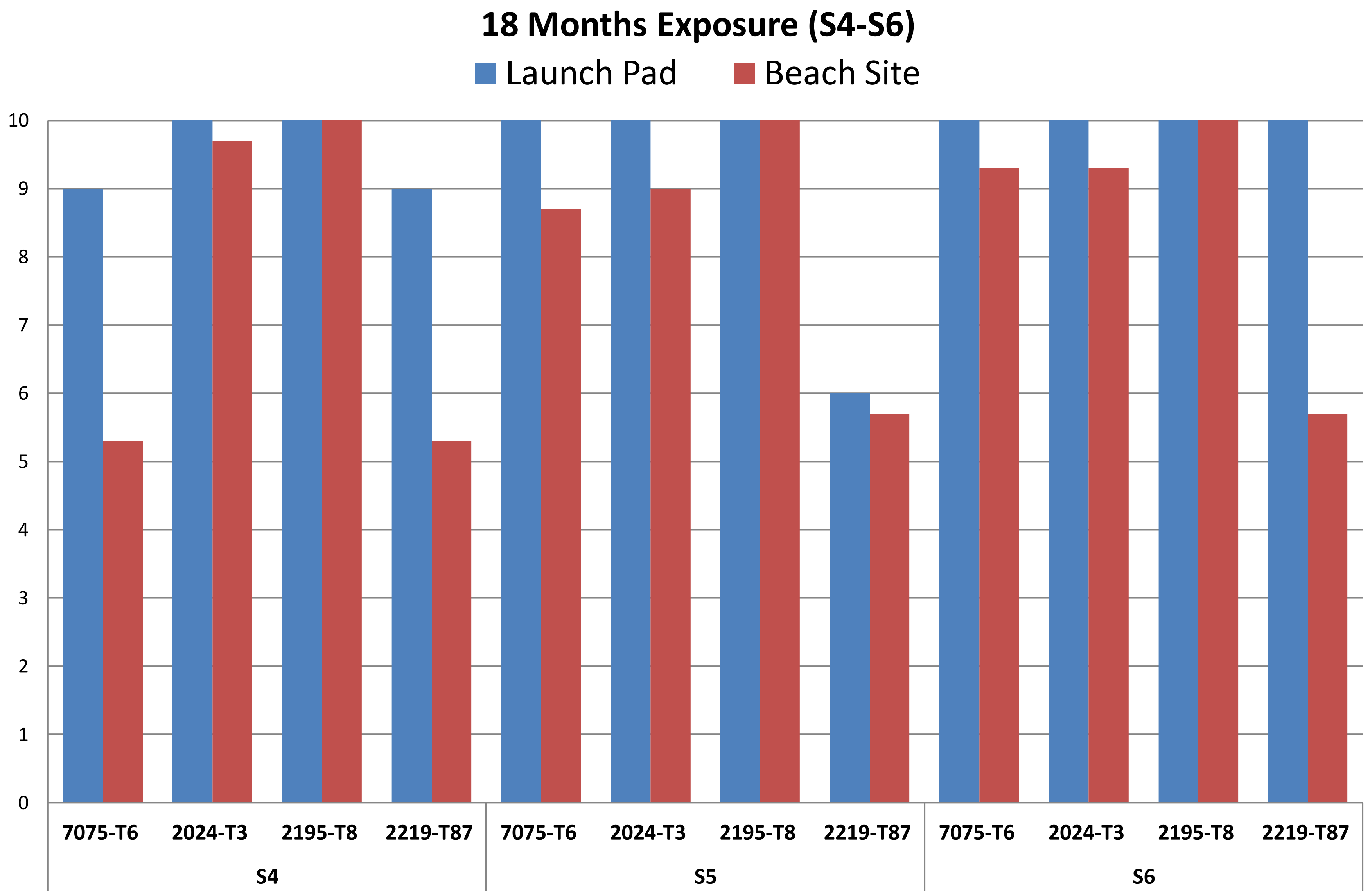
	Coating System	Substrate	18-Months	
			Pad B	Beach
C	C1	2024-T3	10	10
	C2	2024-T3	10	8.3
N	S1	2024-T3	10	10
T	S2	2024-T3	5.0	2.3
	S3	2024-T3	10	8.3
	S4	2024-T3	10	9.7
	S5	2024-T3	10	9
	S6	2024-T3	10	9.3
H	S7	2024-T3	6.3	0
	S8	2024-T3	10	8.3
P	S9	2024-T3	10	5

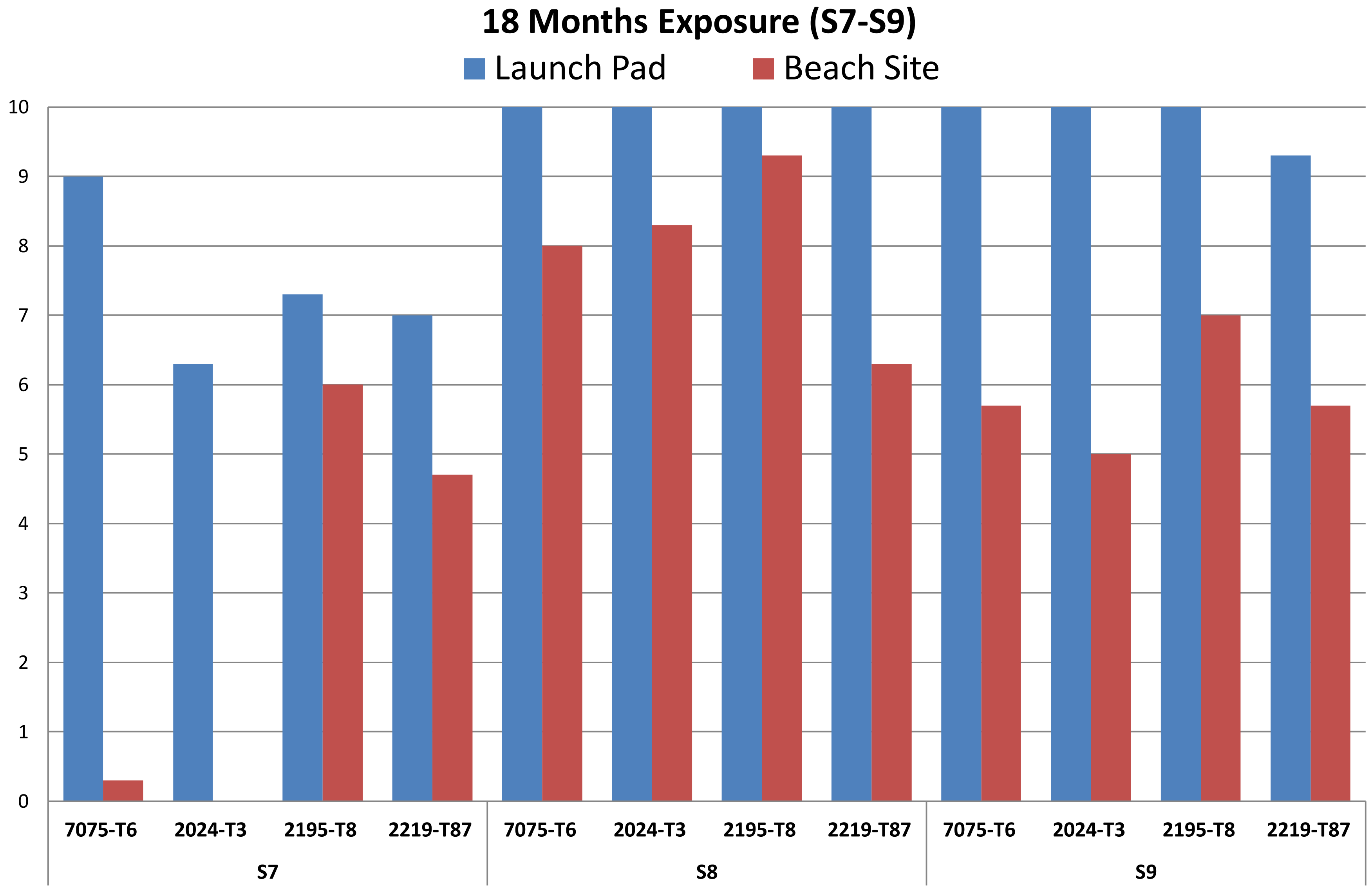
	Coating System	Substrate	18-Months	
			Pad B	Beach
C	C1	7075-T6	9	9
	C2	7075-T6	10	8.3
N	S1	7075-T6	10	9.3
T	S2	7075-T6	6	0
	S3	7075-T6	10	9.3
	S4	7075-T6	9	5.3
	S5	7075-T6	10	8.7
	S6	7075-T6	10	9.3
H	S7	7075-T6	9	0.3
	S8	7075-T6	10	8
P	S9	7075-T6	10	5.7

	Coating System	Substrate	18-Months	
			Pad B	Beach
C	C1	2195-T8	10	10
	C2	2195-T8	10	10
N	S1	2195-T8	10	10
T	S2	2195-T8	7	7
	S3	2195-T8	10	10
	S4	2195-T8	10	10
	S5	2195-T8	10	10
	S6	2195-T8	10	10
H	S7	2195-T8	7.3	6
	S8	2195-T8	10	9.3
P	S9	2195-T8	10	7

	Coating System	Substrate	18-Months	
			Pad B	Beach
C	C1	2219-T87	10	10
	C2	2219-T87	10	8.3
N	S1	2219-T87	10	8.3
T	S2	2219-T87	6.7	3.7
	S3	2219-T87	10	4
	S4	2219-T87	9	5.3
	S5	2219-T87	6	5.7
	S6	2219-T87	10	5.7
H	S7	2219-T87	7	4.7
	S8	2219-T87	10	6.3
P	S9	2219-T87	9.3	5.7


18 Months Exposure (S1-S3)
Launch Pad
Beach Site
10
9
8
7
6
5
4
3
2
1
0
7075-T6
2024-T3
2195-T8
2219-T87
7075-T6
2024-T3
2195-T8
2219-T87
7075-T6
2024-T3
2195-T8
2219-T87
S1
S2
S3


18 Months Exposure (S4-S6)
Launch Pad
Beach Site
10
9
8
7
6
5
4
3
2
1
0
7075-T6
2024-T3
2195-T8
2219-T87
S4
7075-T6
2024-T3
2195-T8
2219-T87
S5
7075-T6
2024-T3
2195-T8
2219-T87
S6


18 Months Exposure (S7-S9)
Launch Pad
Beach Site
0
1
2
3
4
5
6
7
8
9
10
7075-T6
2024-T3
2195-T8
2219-T87
S7
S8
S9

Combined Environment Test chamber and Experimental Design

Setting	UV	Ozone	Salt Mix	Bare			Coated - System 2	Coated - System 7	Bare			Bare			Coated - Control	DATA POINTS
				Hours Exposure			Hours Exposure	Hours Exposure	Hours Exposure			Hours Exposure			Hours Exposure	
				24h	48h	72h	24h 48h 72h	24h 48h 72h	24h	48h	72h	24h	48h	72h	24h 48h 72h	
				Substrate AL-2024			Substrate AL-2024	Substrate AL-2024	Substrate ST-1010			Substrate Ag			Substrate AL-2024	
Setting 1	Low	Low	B117 - 5%	4	4	4	4	4	4	4	4	1	1	1	1	36
Setting 2	High	Low	B117 - 5%	4	4	4	4	4	4	4	4	1	1	1	1	36
Setting 3	Low	High	B117 - 5%	4	4	4	4	4	4	4	4	1	1	1	1	36
Setting 4	High	High	B117 - 5%	4	4	4	4	4	4	4	4	1	1	1	1	36
Setting 5	Low	Low	KSC (XPS)	4	4	4	4	4	4	4	4	1	1	1	1	36
Setting 6	High	Low	KSC (XPS)	4	4	4	4	4	4	4	4	1	1	1	1	36
Setting 7	Low	High	KSC (XPS)	4	4	4	4	4	4	4	4	1	1	1	1	36
Setting 8	High	High	KSC (XPS)	4	4	4	4	4	4	4	4	1	1	1	1	36
			Data Points:	32	32	32	32	32	32	32	32	8	8	8	8	**288**
				Total: 96			Total: 32	Total: 32	Total: 96			Total: 24			Total: 8	

Life Cycle Corrosion of Space Vehicles

Understanding the KSC Performance Environment:

Details:

- Characterize KSC Environment (XPS) (Salt Solution)
- Determine ideal testing conditions and equipment
- Design 2k-Factorial Experiment
- Compare results to
  - Phase II Testing
  - Corrosion Rate Testing at KSC (Pad and Beach)
  - Historical Corrosion Rates at KSC (Beach)

- Utilize Silver as Indicator Substrate for Testing / Analysis

Factors of consideration:

- Temperature, Humidity, Salt Type, Salt Concentration, Light (UV / Xeon-Arc), Ozone (KSC < 50ppb on Avg.)

Equipment of consideration:

- Combination of B117 Salt-Fog Cabinet, UV / Xeon-Arc Chamber, Thermotron
- Modified Corrosion Cabinet w/ UV Lights & Ozone

Fresh sample

1 week – B117

1 month – B117

22 hours - B117
O3 +UV

Combined Environment Testing

Final Settings

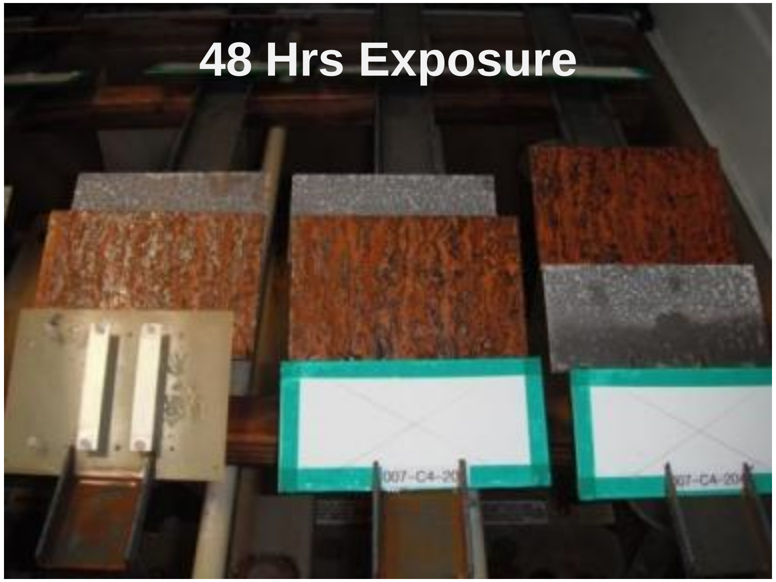
Ozone:
- Ozone High = 800ppb
- Ozone Low = 100ppb

Light:
- UV High = 86% of UV Bulb Intensity
- UV Low = 10% of UV Bulb Intensity

Salt:
- Salt Mixture 1 - 5% NaCl
- Salt Mixture 2 – XPS Determined
  - Simulated KSC Salt Solution
    - (H_2SO_4, NaCl, CuCl, $Mg(OH)_2$, $CaCl_2$, Cu_2O, MgF_2, $Cu(OH)_2$, Ammonia)
    - pH ≈ 5.4

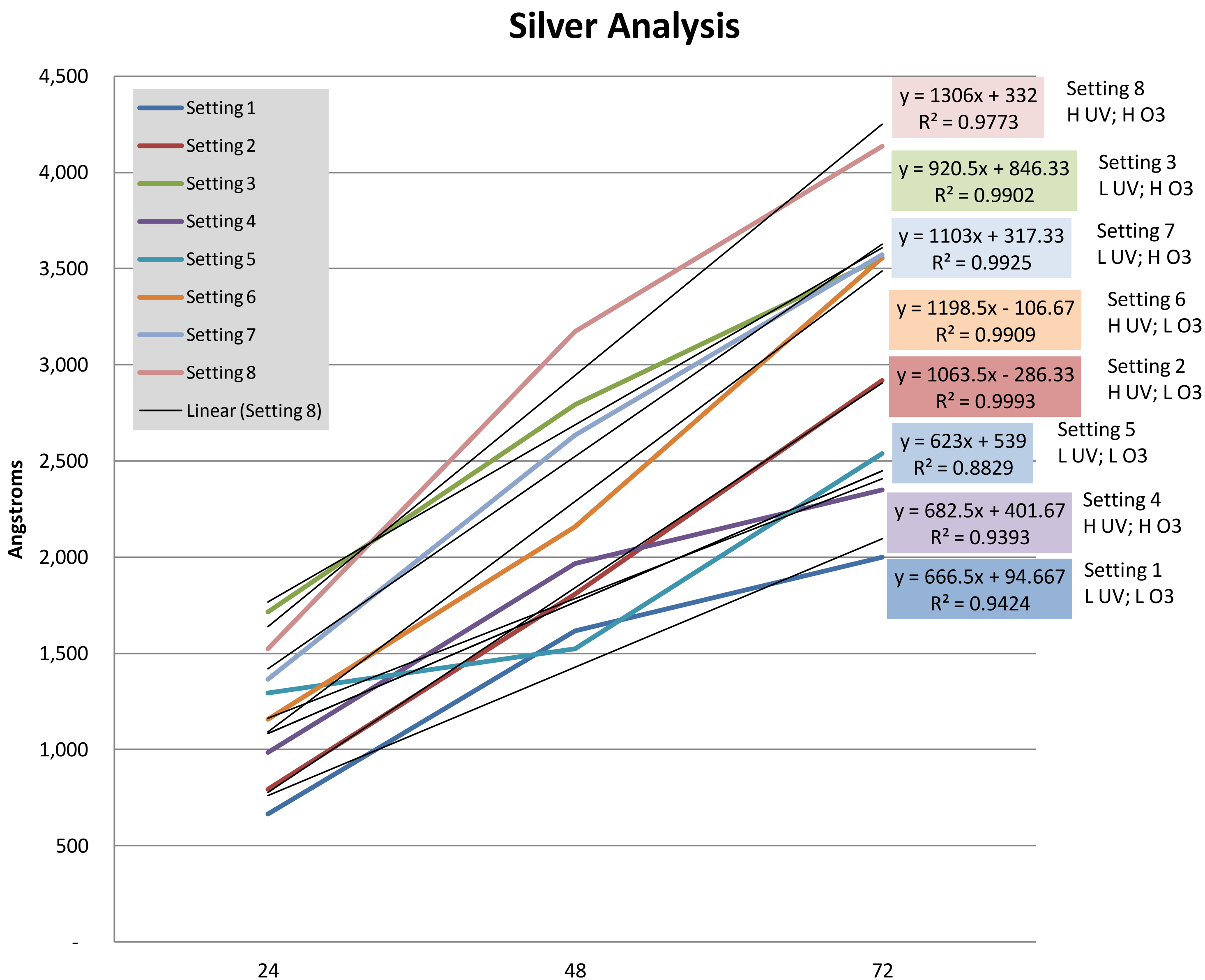
Temperature:
- Constant - 46° C

Humidity:
- ≈ 90 - 100%



National Aeronautics and Space Administration (NASA)

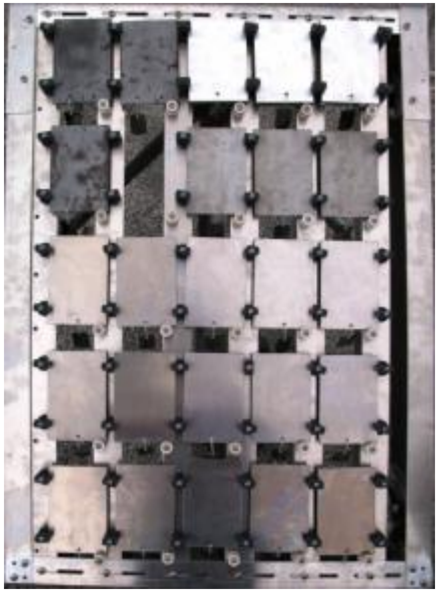
Initial Results – (NO DOE Analysis yet)



Hex Chrome Free Coatings for Electronics (NASA-DoD)

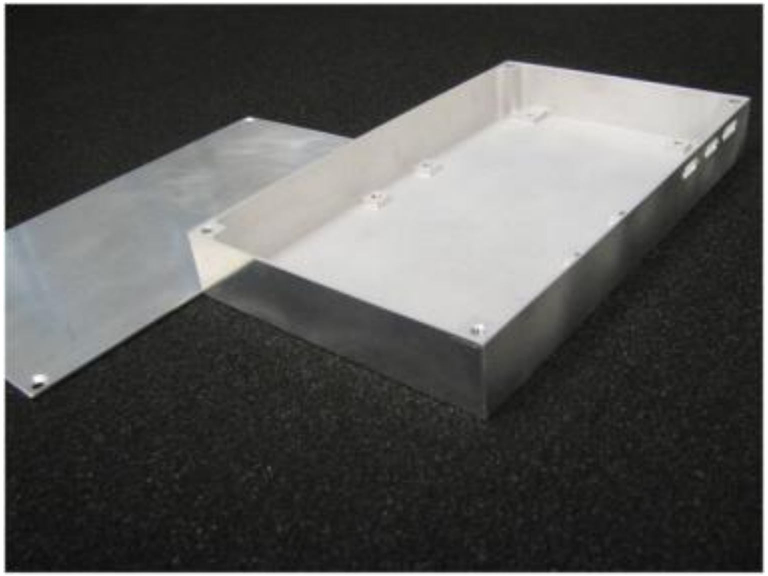
Substrates:

- 6061-T6
- 7075-T73
- 2024-T3
- 5052-H32



Pretreatments:

- Alodine 1600 (Baseline)
- Metalast HF
- Metalast HFEPA
- SurTec 650
- SurTec 650 C
- Alodine T 5900 RTU
- Iridite NCP



Moving Toward Solutions

Comprehensive Evaluation and Transition of Non Chromated Paint Primers

{ESTCP Project WP-201132}

Underlying Issue:

NASA and the US Department of Defense (DoD) continue to search for an alternative to hexavalent chromium in coatings and plating applications that meet their performance requirements in corrosion protection, cost, operability and health and safety; while underlining that performance must be equal to or greater than existing systems.

NASA TEERM Support:

2011 - Provide data, specifications, lessons learned and future material considerations in support of the Comprehensive evaluation and Transition of Non Chromated Paint Primers (ESTCP Project WP-201132) project.

2012 and beyond will focus on the testing of promising coatings identified during the first year of the project.

Comprehensive Evaluation and Transition of Non Chromated Paint Primers

{ESTCP Project WP-201132}

Focus of Testing:

Working jointly with the DOD, NASA Centers and industry, this project will focus on testing of coatings containing no hexavalent chromium that either have been approved for use within the DOD or private sector on aerospace equipment or have shown promise in previous testing by one or more of the project stakeholders. Additionally, some lower TRL materials, such as smart-coatings will be considered for evaluation.

Anticipated benefits to the Government for this project include:

Project builds off previously successful NASA, DOD and ESTCP sponsored testing. Reduced risk for materials obsolescence of hex-chrome coatings with the discovery of coatings that perform to the requirements for current and future Programs within NASA, and the DOD.